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N TYPE IMPURITY DOPING USING IMPLANTATION OF P_2^+ IONS OR As_2^+ IONS

BACKGROUND OF THE INVENTION

(1) FIELD OF THE INVENTION

This invention relates to the use of an ion implantation beam of P_2^+ ions or As_2^+ ions to dope N type shallow junction source/drain regions or gate electrodes used in devices with shallow source/drain regions. Use of the P_2^+ ions or As_2^+ ions uses lower ion density and higher beam energy resulting in improved throughput and ion source life.

(2) DESCRIPTION OF THE RELATED ART

As junctions become very shallow the use of P^+ ion beams or As^+ ion beams becomes a problem because beam energies must be kept very low while the beam ion densities must be kept very high. These requirements leads to reduced ion source life and reduced wafer throughput. This

invention overcomes this problem using P_2^+ ion beams or As_2^+ ion beams.

U.S. Pat. No. 5,155,369 to Current describes a method of using two doses of ions in an ion beam to provide implantation for shallow junction devices. A first dose of ions is implanted to produce a damaged layer through which a second dose of ions is directed. The damaged layer scatters the second dose of ions and channeling is avoided.

In their book "Silicon Processing for the VLSI Era, Volume I", by Wolf and Tauber, Lattice Press, 1990, page 327, Wolf and Tauber discuss ion implantation using doubly charged species.

SUMMARY OF THE INVENTION

Ion implantation is used frequently in the manufacture of integrated circuits. Ion beams are used to implant impurities into semiconductor wafers to provide doping for source/drain regions, polysilicon electrode patterns, and the like. In ion beam implantation the beam energy and ion density are chosen to provide the desired impurity profile after implantation. One problem encountered as device geometries become smaller and source/drain junction depths become smaller is that the ion beam energy must become lower, in some cases less than 10 KeV. At these low energies it is difficult to obtain sufficient ion beam density resulting in lower throughput rates and increased implant cycle times, which directly impact cost. In addition the ion sources are stressed by these conditions and must be replaced with increased frequency.

It is a principle objective of this invention to provide a method of implanting phosphorous in source/drain regions using ion beam implantation with increased beam energy in applications having very shallow junctions.

It is another principle objective of this invention to provide a method of implanting arsenic in source/drain regions using ion beam implantation with increased beam energy in applications having very shallow junctions.

It is another principle objective of this invention to provide a method of implanting phosphorous in polysilicon electrodes using ion beam implantation with increased beam energy in applications having very shallow junctions.

It is another principle objective of this invention to provide a method of implanting arsenic in polysilicon electrodes using ion beam implantation with increased beam energy in applications having very shallow junctions.

These objectives are achieved by using ion sources such as solid phosphorous, phosphine gas, solid arsenic, or SDS arsine in the ion beam apparatus. The magnetic analyzer of the ion beam apparatus is then adjusted to select either the P_2^+ or the As_2^+ isotopes for the ion beam. These ion beams can then be implanted using energies of 20 KeV or greater.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a schematic view of an ion beam apparatus.

Fig. 2 shows a cross section view of a part of an integrated circuit wafer showing an ion beam being used to implant impurities into source/drain regions.

Fig. 3 shows a cross section view of a part of an integrated circuit wafer showing an ion beam being used to implant impurities into a polysilicon gate electrode.

Fig. 4 shows an atomic mass unit spectrum of a solid phosphorous source with a beam energy of 30 KeV showing beam current as a function of atomic mass units.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of this invention will now be described with reference to Figs. 1-4. Fig. 1 shows a schematic view of an ion beam apparatus. Different ion beam systems may differ from the one shown and described herein but certain key features will be common to all ion beam systems. The ion beam apparatus has an ion source 10 which uses a small accelerating voltage to inject an ion beam 24 into an evacuated enclosure 12. Ion sources can be solid materials or gasses such as solid phosphorous, phosphine gas, solid arsenic, or SDS arsine.

Referring again to Fig. 1, the beam then enters a magnetic analyzer 14 which is selected to select particles with a particular mass to charge ratio for the beam 25 exiting the magnetic analyzer. For the example of an ion source 10 using solid phosphorous or phosphine gas the magnetic analyzer 14 is adjusted to select singly charged P_2 ions which have a mass of 62 atomic mass units and a charge equal to the charge of a single electron. These ions will be designated as P_2^+ ions. Solid phosphorous or phosphine gas provide an abundance of P_2 isotopes. Solid arsenic or SDS arsine can also be used as the ion source 10. In this case the magnetic analyzer 14 is adjusted to select singly charged As_2 ions which have a mass of 150 atomic mass units

and a charge equal to the charge of a single electron. These ions will be designated as As_2^+ ions. Solid arsenic or SDS arsine provide an abundance of As_2 isotopes.

As shown in Fig. 1, the ion beam 25 exiting the magnetic analyzer 14 is then directed through a voltage accelerator/decelerator 16 where the selected beam energy is imparted to the ion beam 25. The ion beam 26 exiting the voltage accelerator/decelerator 16 passes through a scanning system 18 which directs the ion beam. The ion beam exiting the scanning system 18 passes through an energy filter 52, to provide improved energy uniformity, and a plasma flood gun 54, to neutralize any charge buildup on the wafer during ion implantation. The ion beam 27 exiting the plasma flood gun 54 is directed, by the scanning system 18, to the proper location on an integrated circuit wafer 30 which is attached to a wafer holder 20. A coupling mechanism 22 attaches the wafer holder 20 to the evacuated enclosure 12. In this manner the ion beam 27 exiting the scanning system can be used to implant impurities into source/drain regions or into polysilicon electrodes.

Fig. 2 shows a part of the wafer 30 which is held in place by the wafer holder in the evacuated enclosure. The wafer comprises a substrate, in this example a P type silicon substrate, having field oxide isolation regions 34

and a gate oxide layer 36. A gate electrode 40 is formed on the gate oxide layer 36. The ion beam 27 is used to implant impurities into the source/drain regions 38. In this example the ion beam 27 is a P_2^+ ion beam having a beam density of between about 4 X 10^{14} and 6 X 10^{14} ions/cm^2 and a beam energy of between about 20 and 48 KeV. The beam density used is one half that required for a beam of P^+ ions because two phosphorous atoms are implanted for every P_2^+ ion implanted. The beam energy is double that would be required for a beam of P^+ ions because each of the P_2^+ ions have two phosphorous atoms. After the implantation the wafer is rapidly annealed at an anneal temperature of between about 900°C and 1100°C for between about 10 and 20 seconds. This method produces shallow source/drain regions 38 using beam density and energy levels which maintain good throughput and source life.

Fig. 3 also shows a part of the wafer 30 which is held in place by the wafer holder in the evacuated enclosure. The wafer comprises a substrate, in this example a P type silicon substrate, having field oxide isolation regions 34 and a gate oxide layer 36. A polysilicon gate electrode 40 is formed on the gate oxide layer 36. The ion beam 27 is used to implant impurities into the polysilicon gate electrode 40. In this example the ion beam 27 is a P_2^+ ion beam having a beam density of between about 4 X 10^{14} and

6 X 10^{14} ions/cm^2 and a beam energy of between about 20 and 48 KeV. The beam density used is one half that required for a beam of P^+ ions because two phosphorous atoms are implanted for every P_2^+ ion implanted. The beam energy is double that would be required for a beam of P^+ ions because each of the P_2^+ ions have two phosphorous atoms. After the implantation the wafer is annealed at an anneal temperature of between about 900°C and 1100°C for between about 10 and 20 seconds. This method produces good conductivity for the polysilicon gate electrode 40 using beam density and energy levels which maintain good throughput and source life.

Referring again to Fig. 2, an ion beam 27 of As_2^+ ions can be used to implant impurities into the source/drain region 38. The wafer comprises a substrate, in this example a P type silicon substrate, having field oxide isolation regions 34 and a gate oxide layer 36. In this example the ion beam 27 is an As_2^+ ion beam having a beam density of between about 4 X 10^{14} and 6 X 10^{14} ions/cm^2 and a beam energy of between about 20 and 48 KeV. The beam density used is one half that required for a beam of As^+ ions because two arsenic atoms are implanted for every As_2^+ ion implanted. The beam energy is double that would be required for a beam of As^+ ions because each of the As_2^+ ions have two arsenic atoms. After the implantation the wafer is annealed at an anneal temperature of between about 900°C and

1100°C for between about 10 and 20 seconds. This method produces shallow source/drain regions 38 using beam density and energy levels which maintain good throughput and source life.

Referring again to Fig. 3, an ion beam 27 of As_2^+ ions can be used to implant impurities into the polysilicon gate electrode 40. The wafer comprises a substrate, in this example a P type silicon substrate, having field oxide isolation regions 34 and a gate oxide layer 36. In this example the ion beam 27 is an As_2^+ ion beam having a beam density of between about 4 X 10^{14} and 6 X 10^{14} ions/cm^2 and a beam energy of between about 20 and 48 KeV. The beam density used is one half that required for a beam of As^+ ions because two arsenic atoms are implanted for every As_2^+ ion implanted. The beam energy is double that would be required for a beam of As^+ ions because each of the As_2^+ ions have two arsenic atoms. After the implantation the wafer is annealed at an anneal temperature of between about 900°C and 1100°C for between about 10 and 20 seconds. This method produces good conductivity for the polysilicon gate electrode 40 using beam density and energy levels which maintain good throughput and source life.